THE EFFECT OF STRAIN RATE ON JUTE FIBRE COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENT FOR THE DEGREE OF

Bachelor of Technology
in
Metallurgical & Materials Engineering

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Under the Guidance of

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CERTIFICATE

This is to certify that the thesis entitled, “The Effect of Strain Rate on Jute Fiber Composites” submitted by Ms. Lipsa Mahapatra in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Electrical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by her under my supervision and guidance .

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date : 30/4/2007

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ABSTRACT

The present experimental work is aimed to study the effect of different loading rate on mechanical behaviour of jute composites. Surface modification was done in order to get better interfacial bonding between jute and resin. These composites showed insensitive behavior at high loading rate. The loading rate behavior of the composite was compared on the basis of different surface treatments of jute fiber.

Composites are fiber reinforced materials. Fibers must have high strength and high elastic modulus while the matrix must be ductile and non-reactive with the fibers.Now a days natural fibers are used as reinforcements in composites. Fiber–reinforced polymer matrix composites are gaining potential application in structural and nonstructural areas.

The raw jute fibers are cut into desired number of equal size pieces and then alkali treatment of these jute fibers is done in 5%NaOH.Fabrication of composites is done by Hand lay-up technique where alternate layers of resin mix and jute fibres are placed and loaded in hydraulic press.Finally 3-point bend test is done in INSTRON 1195 machine.

The loading rate insensitivity of composites in sense of stress at yield and ILSS values at higher loading rate were obtained which is explained on the basis of changing failure modes as the crosshead velocity changes

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INTRODUCTION

INTRODUCTION

Over the past few decades, we find that polymer have replaced many of the conventional metals/materials in various applications. This is possible because of the advantages polymers offer over conventional materials. The most important advantages of using polymers are the ease of processing, productivity, and cost reduction. In most of these applications, the properties of polymers are modified using fillers and fibers to suit the high strength/high modulus requirements. Fiber–reinforced polymer matrix composites are gaining potential application in structural and nonstructural areas due to having the interesting properties like high specific stiffness and strength, good fatigue performance and damage tolerance, corrosion resistance, low thermal expansion, non-magnetic properties, and low energy consumption during fabrication.

Composite is a type of material consisting of two or more distinguishable materials. The constituting materials of the composites are :-

1) Binder or Matrix
2) Reinforcement

The matrix holds the reinforcement in an orderly pattern and also helps in transferring load among the reinforcements.

Reinforcement is usually much stronger and stiffer.

Natural fibers have recently attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials. These natural fibers are low-cost fibers with low density and high specific properties. These are biodegradable and non -abrasive, unlike other reinforcing fiber. Different loading conditions are expected in many of the applications where natural fiber composites find use as potential and promising materials. Composite materials are expected to be exposed to variations in loading rates when used in practical conditions.

Chapter 2

LITERATURE REVIEW

LITERATURE REVIEW

2.1 JUTE FIBRE

For our project we are using jute fiber as the reinforcement and polyester resin as the matrix to fabricate the composite.

2.1.a STRUCTURE OF JUTE FIBRE:

Jute fibers mainly consist of :-

a) Cellulose: Cellulose is a hydrophilic glucan polymer consisting of a linear chain of 1,4-b-bonded anhydroglucose units which contains alcoholic hydroxyl groups. These hydroxyl groups form intramolecular hydrogen bonds inside the macromolecule itself and among other cellulose macromolecules as well as with hydroxyl groups from the air. Therefore, all of the jute fibres are hydrophilic in nature; their moisture content reaches 8–12.6%.

b) Hemi-cellulose: Hemicellulose is responsible for the biodegradation, moisture absorption, and thermal degradation of the fiber as it shows least resistance.

c) Lignin: Lignin is a phenolic compound, generally resistant to microbial degradation, but the pretreatment of fibre renders it susceptible to the cellulose enzyme. Lignin is a biochemical polymer which functions as a structural support material in plants. Lignin is believed to be linked with the carbohydrate moiety through two types of linkages, one alkali sensitive and the other alkali resistant. The alkali sensitive linkage forms an ester-type combination between lignin hydroxyls and carboxyls of hemicellulose uronic acid. The ether-type linkage occurs through the lignin hydroxyls combining with the hydroxylof cellulose. This is resistance to microbial and thermal degradation but causes UV-degradation.

Typical composition of jute fiber:

- Cellulose- 61 to 71.5%
- Lignin- 12 to 13%
- Hemi-cellulose- 13.6 to 20.4%

- Pectin- 0.2%
- Moisture- 12.6%

2.1.b PROPERTIES:

The natural fibers exhibit considerable variation in diameter along with the length of individual filaments. The modulus of fiber decreases with increase in diameter The properties such as density, electrical resistivity, ultimate tensile strength, initial modulus depend on:

- Internal structure of the fiber.
- Chemical composition.
- Angle between the axis of the fiber and the fibril.
- Size
- Processing methods adopted for the extraction of fibers.

The strength and stiffness correlate with the angle between axis and fibril of the fiber, i.e the smaller this angle, the higher the mechanical properties; the chemical constituents and complex chemical structure of natural fibers also affect the properties considerably. The lignin content of the fibers influences its structure properties and morphology. The waxy substances of natural fibers, generally influence the fiber's wettability and adhesion characteristics.

For jute fiber:

Density- 1.3to 1.45 gm/cm3

Tensile strength- 393 to 773 MPa

Young's modulus- 55MPa

Elongation at break- 1.16 to 1.5%

Fibrillar angle- 8^0

Less energy required for processing.

2.1.c ADVANTAGES:

1) *Biodegradable:* Natural fibers (lignocellulosics) are degraded by biological organisms since they can recognize the carbohydrate polymers in the cell wall.
2) *Non-abrasive*
3) *Low density:* As its density is low, the volume occupied by the same mass of jute fiber is more than that of synthetic fiber. So it is very cost effective.
4) *High specific modulus:* this is the ratio of tensile modulus to specific gravity which is high for jute fiber.
5) Convenience of forming complex shapes, parts in a single moulding process.
6) It has good impact properties.
7) It is renewable
8) It has high toughness.
9) It can be recycled.

JUTE FIBER vs GLASS FIBRE

PROPERTIES	JUTE FIBRE	GLASS FIBRE
Tensile Strength	393MPa	3400MPa
Young’s Modulus	55MPa	72MPa
Specific gravity	1.3	2.5
Specific Modulus	38MPa	28MPa
Disposal	Biodegradable	Non-Biodegradable
Energy Consumption	Low	High
Recycling	Yes	No
Renewability	Yes	No
Abrasion to machine	No	Yes
Cost	Low	Low but higher than jute

Table 2.1

Though jute fibres’ mechanical properties are much lower than those of glass fibres , their specific properties, especially stiffness,

are comparable to the stated values of glass fibres. Moreover, jute fibres are about 50% lighter than glass, and in general cheaper. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements.
The specific properties of the jute fibre composites were in some cases better than those of glass. This suggests that natural fibre composites have a potential to replace glass in many applications that do not require very high load bearing capabilities.

2.1.d DISADVANTAGE:

The main drawback of biofibres is their *hydrophilic nature* which lowers the compatibility with hydrophobic polymeric matrix during composite fabrications. Cellulosic fibers are hydrophilic and absorb moisture. The moisture content of the fibers can vary between 5 and 10%. This can lead to dimensional variations in composites and also affects the mechanical properties of the composites. During processing of composites based on thermoplastics, the moisture content can lead to poor process ability and porous products. Treatment of natural fibers with chemicals or grafting of vinyl monomers can reduce the moisture gain.

To eliminate the problems related to high water absorption, treatment of fibers with hydrophobic aliphatic and cyclic structures has been attempted. These structures contain reactive functional groups that are capable of bonding to the reactive groups in the matrix polymer, e.g., the carboxyl group of the polyester resin. Thus modification of natural fibers is attempted to make the fibers hydrophobic and to improve interfacial adhesion between the fiber and the matrix polymer.

Moisture absorption can be reduced by following methods:

1. *Chemical means:* Chemical reactions with suitable coupling agents which block the hydroxyl group of the jute and make it hydrophobic. The coupling agents are tetrafunctional organometallic compounds based on silicon, titanium, and zirconium and are commonly known as silane, zirconate, or titanate coupling agents.

2. *Polymeric coating:* Coating with polymeric solution which improve the flexural strength and flexural modulus. These modifications improve the fiber matrix wettability and lead to improved bonding.

3. *Graft co-polymerization:* Chemical modification through graft copolymerization provides a potential route for significantly altering their physical and mechanical properties. Chemical grafting involves attaching to the surface of a fiber/filler a suitable polymer with a solubility parameter similar to that of the polymer matrix, which acts as an interfacial agent and improves the bonding between the fiber and the matrix. Graft copolymerization onto cellulose takes place through an initiation reaction involving attack by macrocellulosic radicals on the monomer to be grafted.

4.*Surface modification :* Chemical treatments such as dewaxing ,delignification, bleaching, acetylation, and chemical grafting are used for modifying the surface properties of the fibers and for enhancing its performance.

The other disadvantage is the relatively *low processing temperature* required due to the possibility of fiber degradation and/or the possibility of volatile emissions that could affect composite properties. The processing temperatures for most of the biofibers are thus limited to about 200 ^{0}C, although it is possible to use higher temperatures for short periods. It was found that temperatures below 170°C only slightly affect fiber properties, while temperatures above 170°C significantly dropped tenacity and degree of polymerization. Because of chain scissions, a slight increase in degree of crystallinity was observed.

The thermal degradation of natural fibers is a two-stage process, one in the temperature range 220–280 ^{0} C and another in the range 280–300 ^{0} C. The low-temperature degradation process is associated with degradation of hemicellulose whereas the high-temperature process is due to lignin. The apparent activation energies for the two processes are about 28 and 35 kcal/mol, which correspond to the degradation of hemicellulose and lignin, respectively.

2.2JUTE FIBER COMPOSITES

In jute fiber composites jute fiber is used as reinforcement and following are the resins that can used as matrix:

polypropylene

epoxy

polyester

phenol formaldehyde

Out of the above mentioned resins we are using polyester for our experiments.

2.2.a STRENGTH AND MODULI OF JUTE COMPOSITES:

The modulus and strength of a fiber reinforced composite are given by a " Rule of mixtures". If we apply a tensile force P in the direction of the fiber we can assume that the fiber and the matrix will strain equally

$$P = \sigma_f A_f + \sigma_m A_m$$

where

A_f & A_m are the cross sectional areas of jute fiber and polyester resin matrix.

σ_f & σ_m are the tensile stresses of the fiber and the matrix.

So, the average composite strength is

$$\sigma_c = \sigma_f A_f / A_c + \sigma_m A_m / A_c$$

since we are dealing with elastic behaviour,

$$\sigma_f = E_f\, e_f \text{ and } \sigma_m = E_m e_m.$$

Therefore ,

$$P_c = E_c e_c A_c$$

Assuming $e_c = e_f = e_m$

The modulus of composite is :

$$E_c = E_f\, f_f + E_m f_m$$

f_f is volume fraction of fibers, A_m / A_c represents f_m .

The mechanical properties of jute fiber composites can be enhanced by various surface treatments like alkali treatment, bleaching, dewaxing, cynoethylation etc.

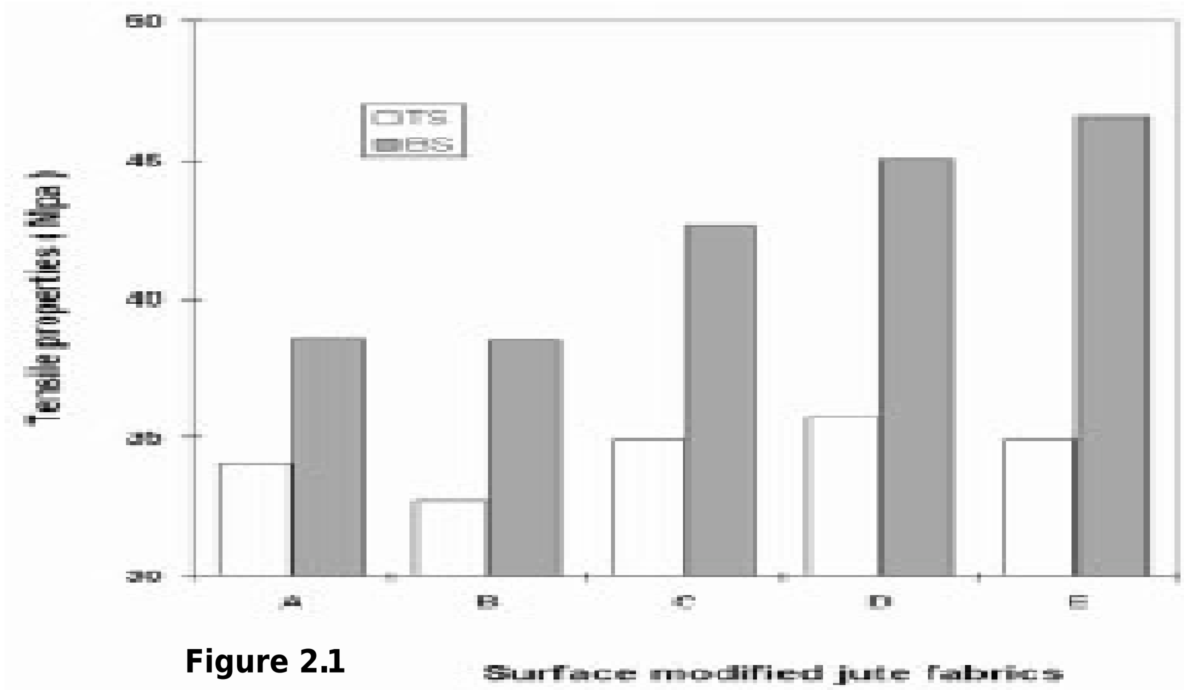


Figure 2.1

As we can interpret from the graph that cynoethylation gives the best properties we will use alkali treatment because apart from providing good properties it is also cost effective and can be carried out easily.

2.2.b APPLICATIONS:

Construction

Construction holds priority for the adaptation of composites in place of conventional materials being used like doors & windows, paneling, furniture, non-structural gratings, long span roof structures, tanks, bridge components and complete bridge systems and other interiors. Components made of composite materials find extensive applications in shuttering supports, special architectural structures imparting aesthetic appearance, large signages etc. with the advantages like corrosion resistance, longer life, low maintenance, ease in workability, fire retardancy.

Automobile

The likely future business opportunities in automotive sector are, Pultruded Driveshafts, RTM Panel, Rocker Arm Covers, Suspension Arms, Wheels and Engine Shrouds, Filament-Wound Fuel Tanks, Electrical Vehicle Body Components and Assembly Units.

Now days jute fiber composites are used in **Bio-Gas plants**.

Chapter 3

EXPERIMENT

EXPERIMENT

3.1 ALKALI TREATMENT

1. Jute fibers are cut into square pieces of size 17*17cm2.
2. The jute fibers are treated in a solution of 5% NaOH where the total volume of solution is 15 times the weight of jute fibers.
3. The fabric is kept in this alkaline solution for 2 hours at room temperature.

4. It is then thoroughly washed in running water then neutralized with a 6% acetic acid solution.
5. It is again washed in running water to remove the last traces of acid sticking to it. Then they are dried in open for 24 hrs.
6. After that it is kept in the furnace for 2.5 hours at 80^0C then again at 110^0C for 1.5 hours.

3.2 FABRICATION

1. Fabrication is done by hand lay-up method.
2. The weight ratio of the fiber and polyester resin is 2:3, hardener and accelerator are 2.6% and 2% of the resin weight, respectively.
3. A milder sheet is laid on a flat surface, on to which mold release spray is sprayed, then a layer of polyester is coated on the sheet.
4. Alternate layers of jute fiber fabric and layers of resin are put.
5. Again a milder sheet is taken and mold release sprayed on to it, and then a layer resin mix is applied to it.

   6. A flat board was then put on this sheet and dead loads were applied on to this prepared composites in cold pressing machine, it is then allowed to cure for 48 hours, after which the prepared sample was ripped off the mold.

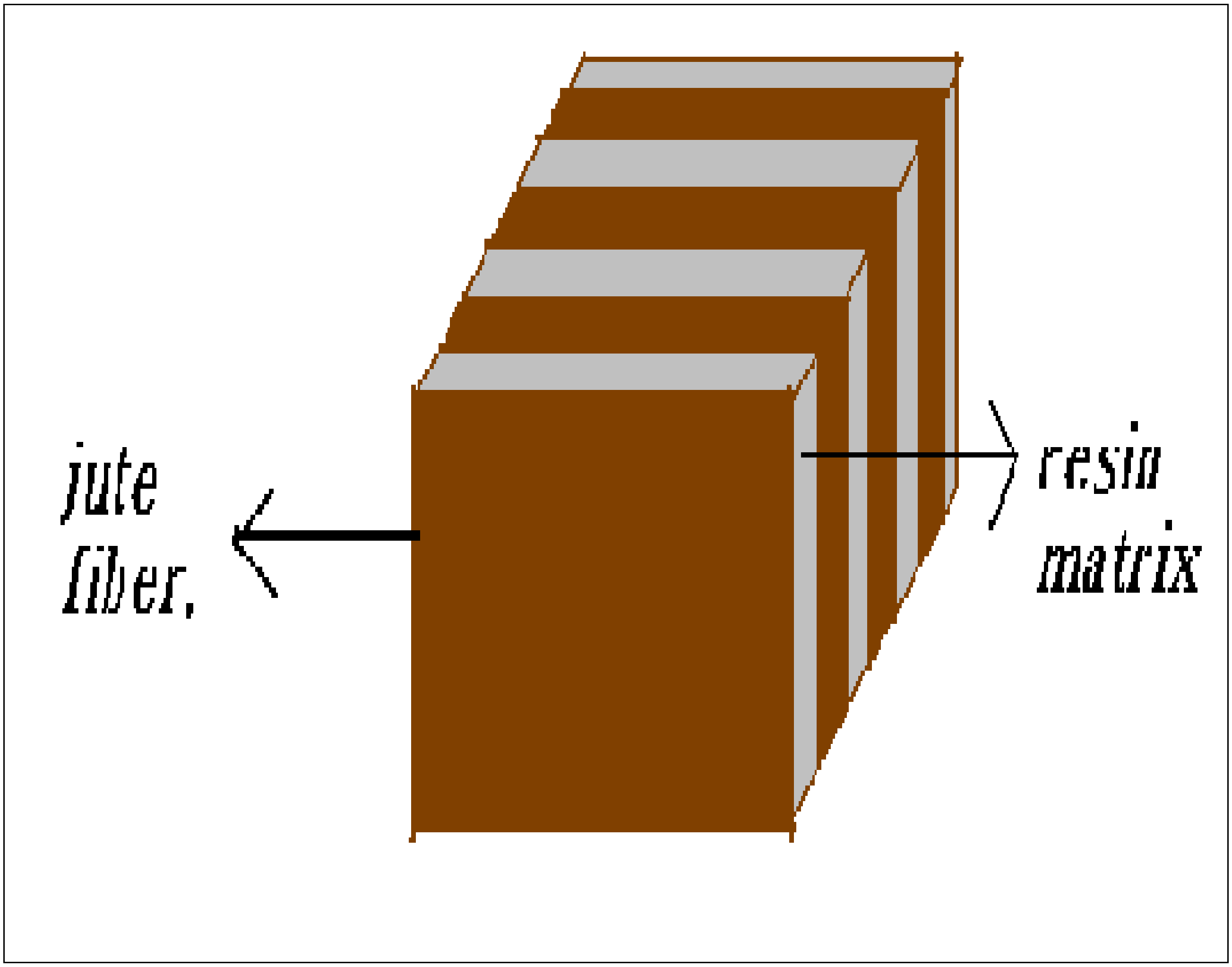


Figure 3.1

3.3 PREPARATION OF SPECIMEN AND TESTING

Specimens of width 12.7 mm are cut using hack saw.

Length = (16 *width) + 12mm.

3-point bend tests for composites are carried out to determine interlaminar shear strength (ILSS)at different cross head speeds 2,10,50,100,500mm/min in Instron 1195 tensile testing machine.

ILSS = 0.75Pb/ bd

where,

ILSS = interlaminar shear strength,

Pb**=** breaking load

b **=** width of the specimen and

d = thickness of the specimen.

Chapter 4

RESULTS & DISCUSSIONS

4.1 ALKALI TREATMENT

Alkali treatment results in:

1. Weight loss during treatment.

    2. The percentage breaking strain is reduced.

1. Better tensile strength.

2. Linear density decreases.

3. Young’s modulus improved.

The NaOH treatment leads to further changes in mechanical properties of the fibers, such as tensile modulus and tensile strength independent of shrinkage during alkali treatment and other treatment parameters.

On the alkali treatment of jute fibers there is removal of lignin and hemicellulose that affects the tensile characteristics of the fibers. When the hemicelluloses are removed, the interfibrillar region is likely to be less dense and less rigid, and thereby makes the fibrils more capable of rearranging themselves along the direction of tensile deformation. When jute fibers are stretched, such rearrangements among the fibrils would result in better load sharing by them, hence higher stress development in the fiber. On the other hand, softening of the inter- fibrillar matrix adversely affects the stress transfer between the fibril and, thereby, the overall stress development in the fiber under tensile deformation. As lignin is removed gradually, the middle lamella joining the ultimate cells is expected to be more plastic, as well as homogeneous, due to the gradual elimination of microvoids, whereas the ultimate cells themselves are only slightly affected.

These changes are possible due to interacting factors such as:

1. Rupture of alkali-sensitive bonds existing between the different components of the fiber as a result of swelling and partial removal of the hemicellulose; the fiber becomes more homogeneous through microvoid elimination (e.g., the stress transfer between ultimate cells improves)

2. Formation of new hydrogen bonds between certain cellulose chains due to the removal of hemicellulose, which normally separates the cellulose chains; this may also occur as a result of the release of initial strains and subsequent readjustments to the chains after intracrystalline swelling action, thus resulting in a probable change in the orientation of noncrystalline cellulose.

3. Change in the parts of crystalline cellulose

4. Changes in the orientation of molecular chains.

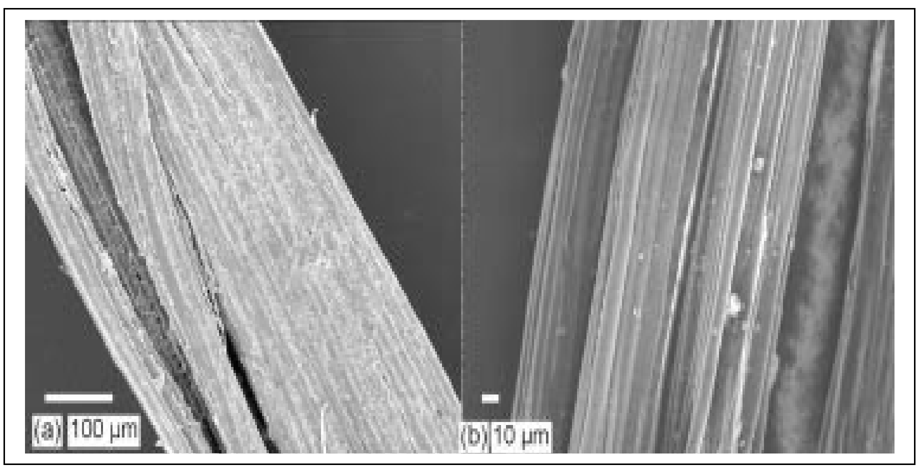
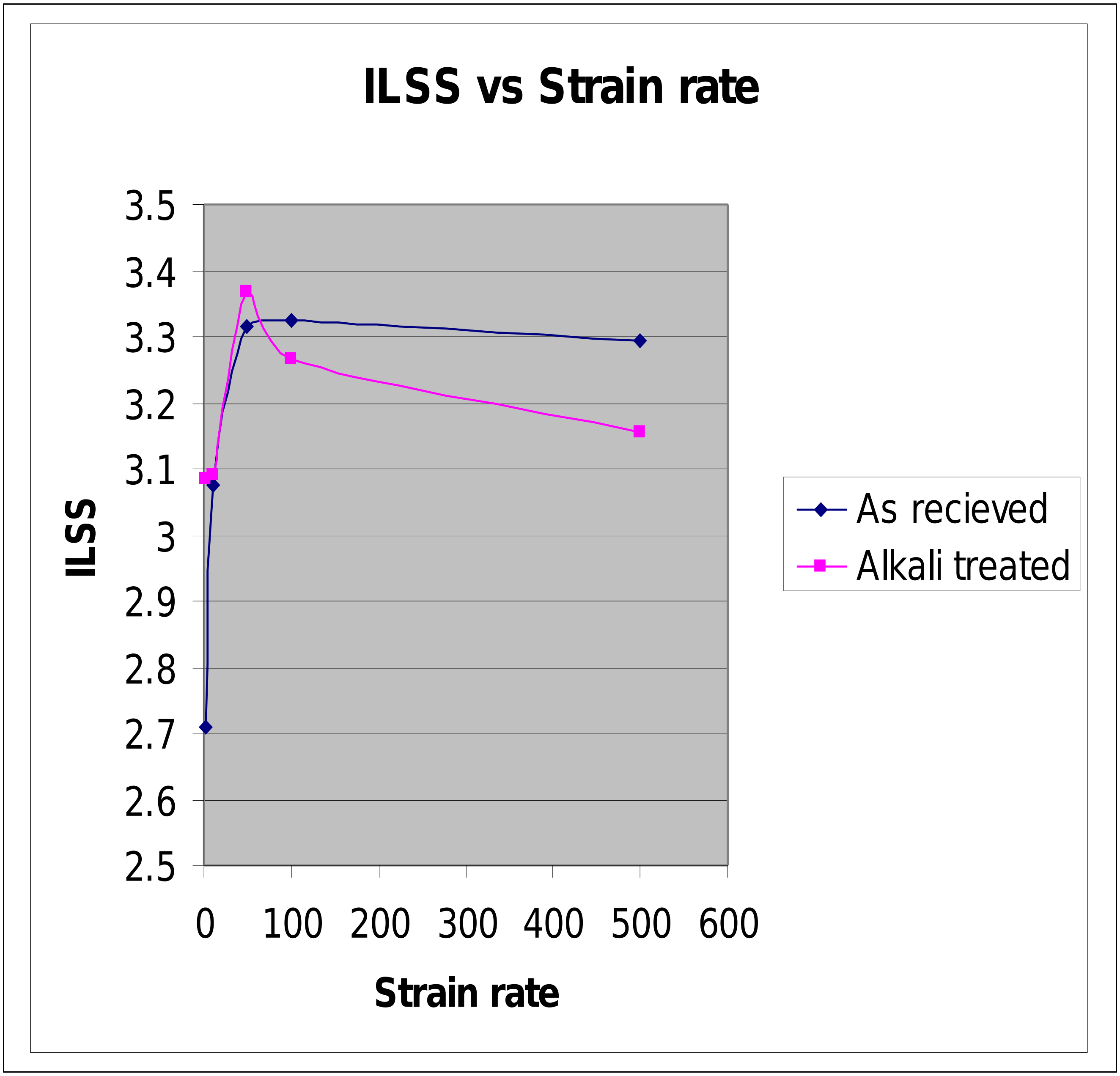


Figure 4.1 (a)
Figure 4.1 (b)

4.2 VARIATION OF ILSS WITH STRAIN RATE

Serial No	Strain rate (mm/min)	ILSS Untreated (N/mm2)	ILSS Alkali treated (N/mm2)
1	2	2.71	3.086
2	10	3.074	3.092
3	50	3.314	3.368
4	100	3.325	3.266
5	500	3.294	3.154

Table 4.1



ILSS vs Strain rate
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
ILSS
0
100
200
300
400
500
600
Strain rate
As recieved
Alkali treated

Figure 4.2

The graph shows that initially ILSS increases with increase in crosshead velocity and then decreases .

Initially ILSS increases due to increase in stiffness of the composite with increasing loading rate. The decrease of ILSS value may be attributed to less time available for crack-blunting at higher crosshead velocity.Insensitivity is observed at still higher crosshead velocity with maximum ILSS value for untreated sample. It may be attributed to change in failure mechanism with increase of crosshead velocity.

Fiber bunch pull-out may be the predominant mode of failure in untreated sample which is more energy absorbing than fiber fracture which is predominant mode of failure in case of treated sample at higher loading rate.

Fiber-matrix adhesion leads to brittle failure since the interfacial bonding influences the intralaminar strength, the interlaminar shear strength and the interlaminar tensile strength.

4.3 VARIATION OF YIELD STRESS WITH STRAIN RATE

Serial No.	Strain rate (mm/min)	Yield stress Untreated (MPa)	Yield stress alkali treated (MPa)
1	2	81.12	72.61
2	10	82.32	77.27
3	50	101.10	87.74
4	100	95.89	78.25
5	500	92.82	77.55

Table 4.2

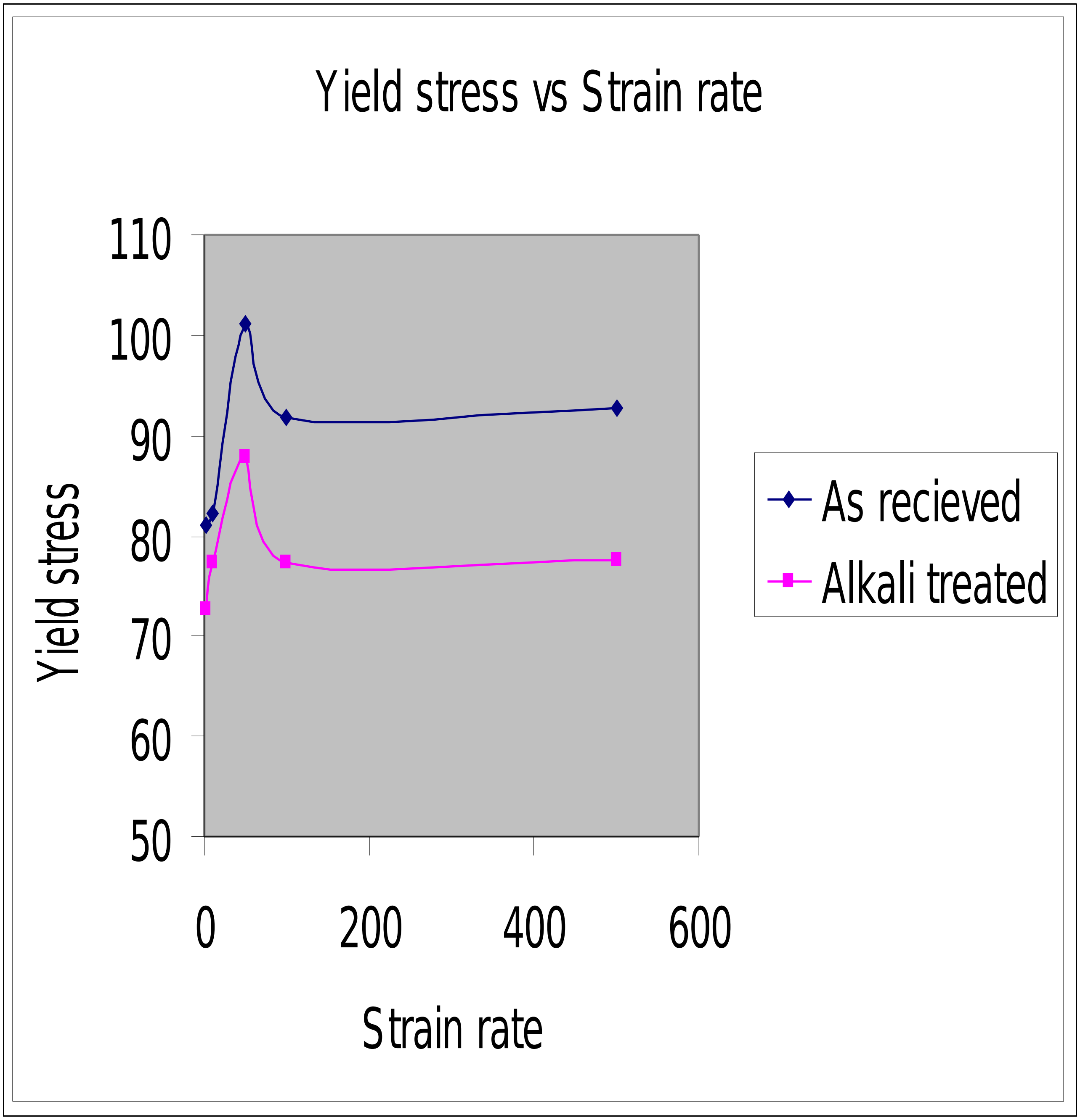


Figure 4.3

Initially the stress at yield increases with cross-head velocity due to increase in

stiffness of the composites. .

Later the stress at yield decreases due to brittle behaviour of matrix and less time available for crack blunting.

At higher loading rate it becomes constant which shows the insensitivity of composite with loading rate because of higher energy absorbing behaviour of jute-fibre at higher loading rates.

The untreated sample show better yield stress at high loading rate than alkali treated sample because of its fiber pull-out failure mechanism unlike simultaneous fracture of resin and matrix in alkali treated sample.

4.4 VARIATION OF ENERGY AT BREAK WITH STRAIN RATE

Serial No.	Strain rate (mm/min)	Energy at break point Untreated (joules)	Energy at break point Alkali treated (joules)
1	2	0.6479	0.6160
2	10	0.5110	0.4809
3	50	0.7120	0.5676
4	100	0.2473	0.1429

5	**500**	**1.088**	**0.8504**

Table 4.3

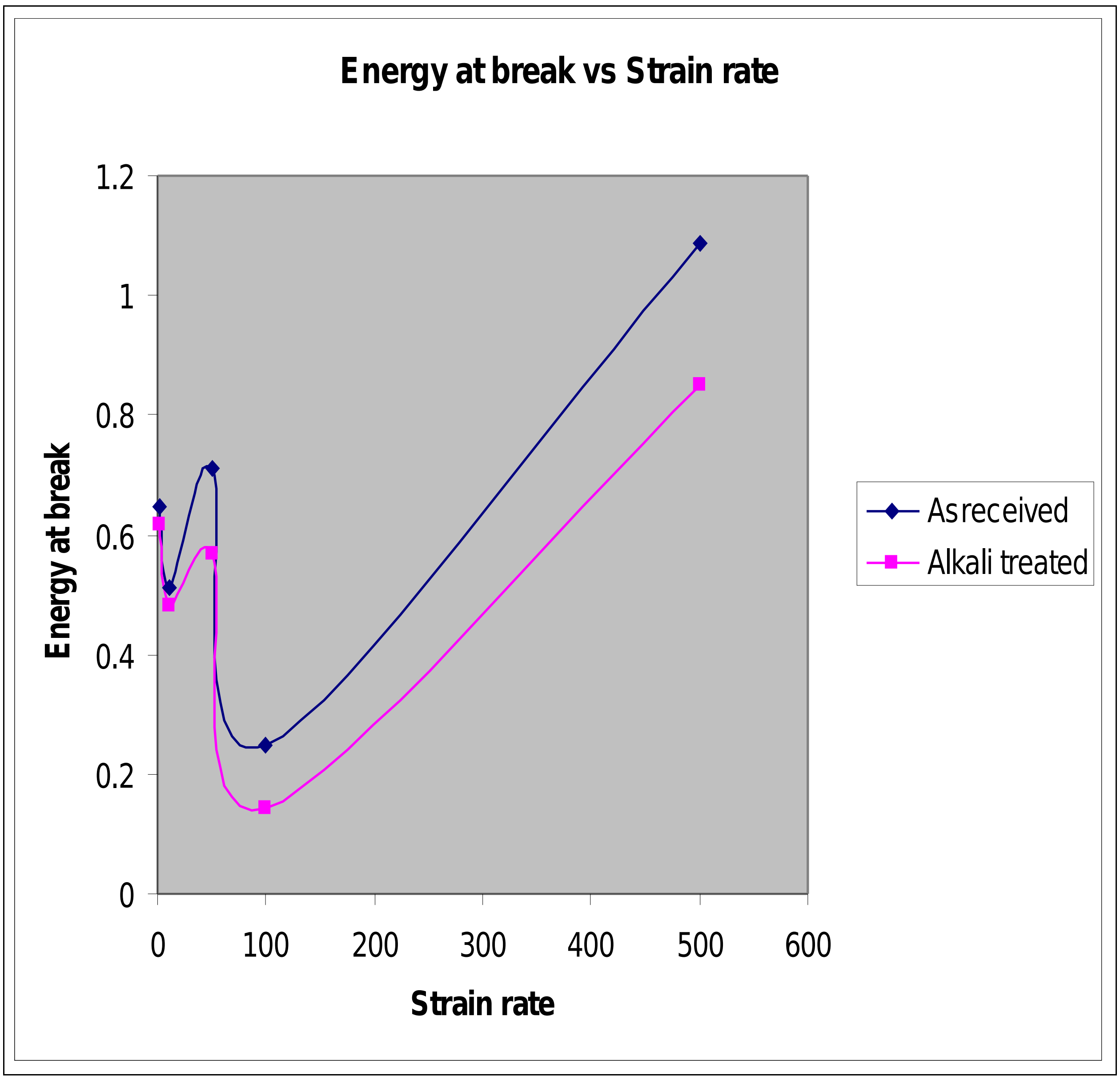


Figure 4.4

At higher loading rates energy absorption is higher. In case of untreated samples energy is higher.

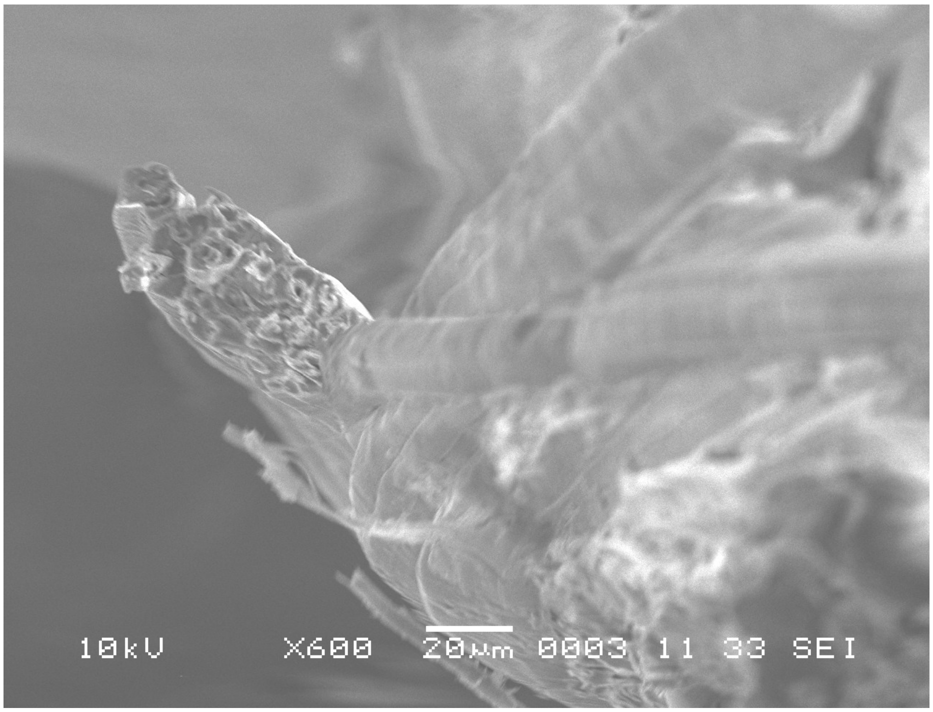


Figure 4.5

Figure 4.6

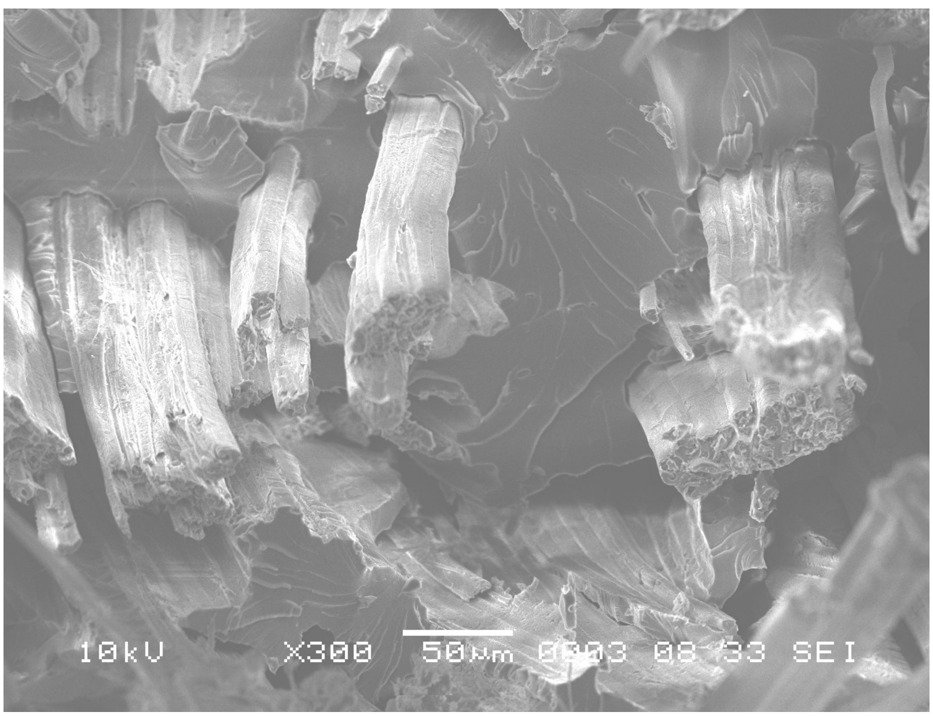


Figure4.7

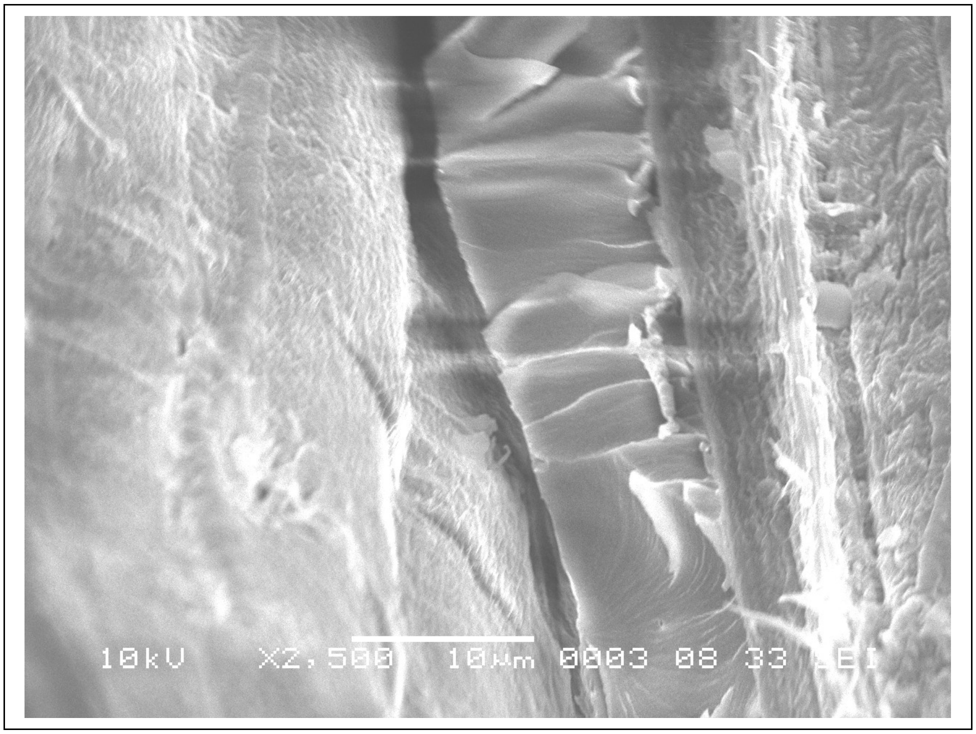


Figure 4.8

Chapter 5

CONCLUSION

CONCLUSION

In this present experimental study, the loading rate behavior of jute fibers composite were examined and reported. Some very interesting and useful results viz. the loading rate insensitivity of composites in sense of stress at yield and ILSS values at higher loading rate were obtained which is explained on the basis of changing failure modes as the crosshead velocity changes.

ILSS values were reported higher in case of untreated samples as fiber pull-out is predominant failure mechanism which is more energy absorbing mechanism than fiber fracture which is prevalent in case of surface treated samples.

Further research is expected to establish the findings in a more concrete way with the change in parameters related to experiment and surface treatment of jute fiber to accomplish better property jute composites.

Also research is going on to use biodegradable resins such as starch and proteins so as to obtain a completely biodegradable composite

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